Resource Exploration on Mars—Applying the Lessons From Earth

April 3, 2017

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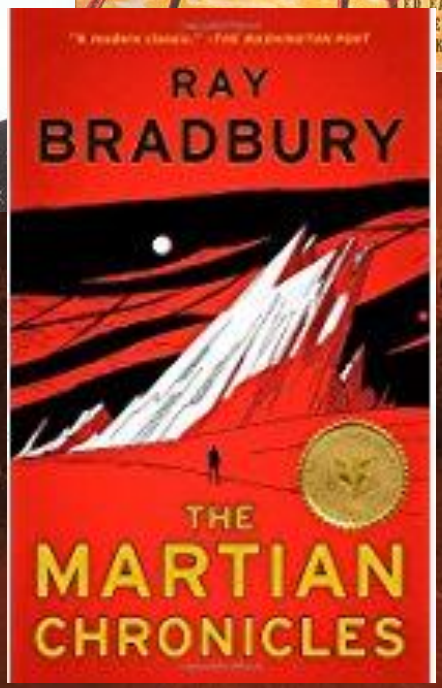
Jet Propulsion Laboratory, California Institute of Technology


VALLEY OF INVISIBLE MEN by EDMOND HAMILTON
SEE BACK COVER
AMAZING STORIES
MARCH
20c
The RAID FROM MARS
by MILES J. BREUER
AND GREAT STORIE


The WAR of the WORLDS

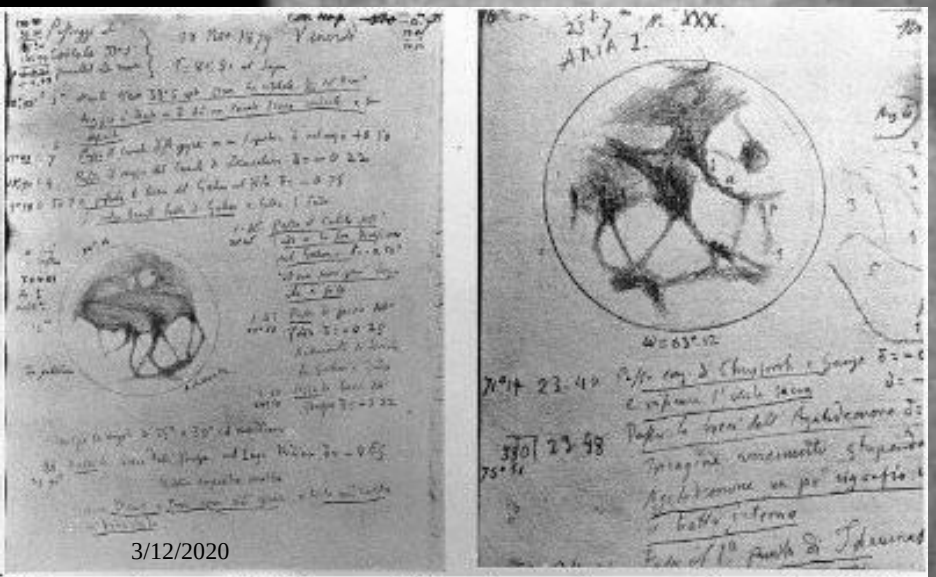

RAY BRADBURY
THE MARTIAN CHRONICLES


EDWARD L. ALPERSON
presents
INVADERS FROM MARS
Photographed in
OLOR
HELENA CARTER ARTHUR FRANZ JIMMY HUNT
WILLIAM CAMERON MENZIES RICHARD BLAKE EDWARD L. ALPERSON, JR. RAOUL KRAUSHAAR

Source: www

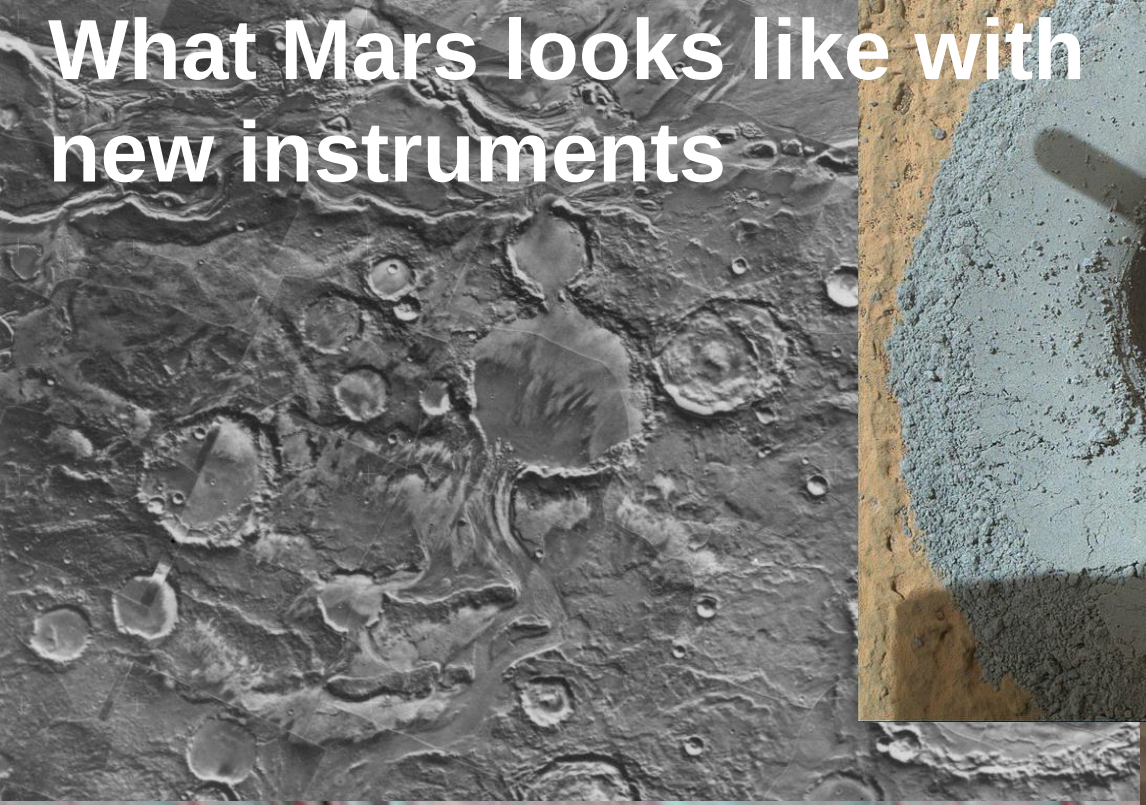
What Mars looked like with old instruments

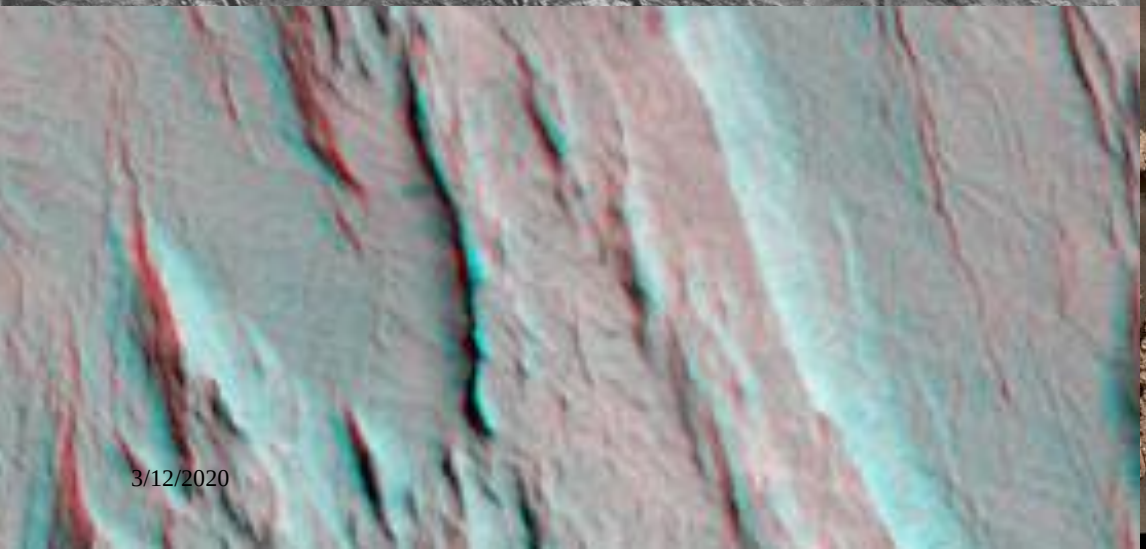
Giovanni Virginio Schiaparelli



Pages from Schiaparelli's observing notebook, 1879

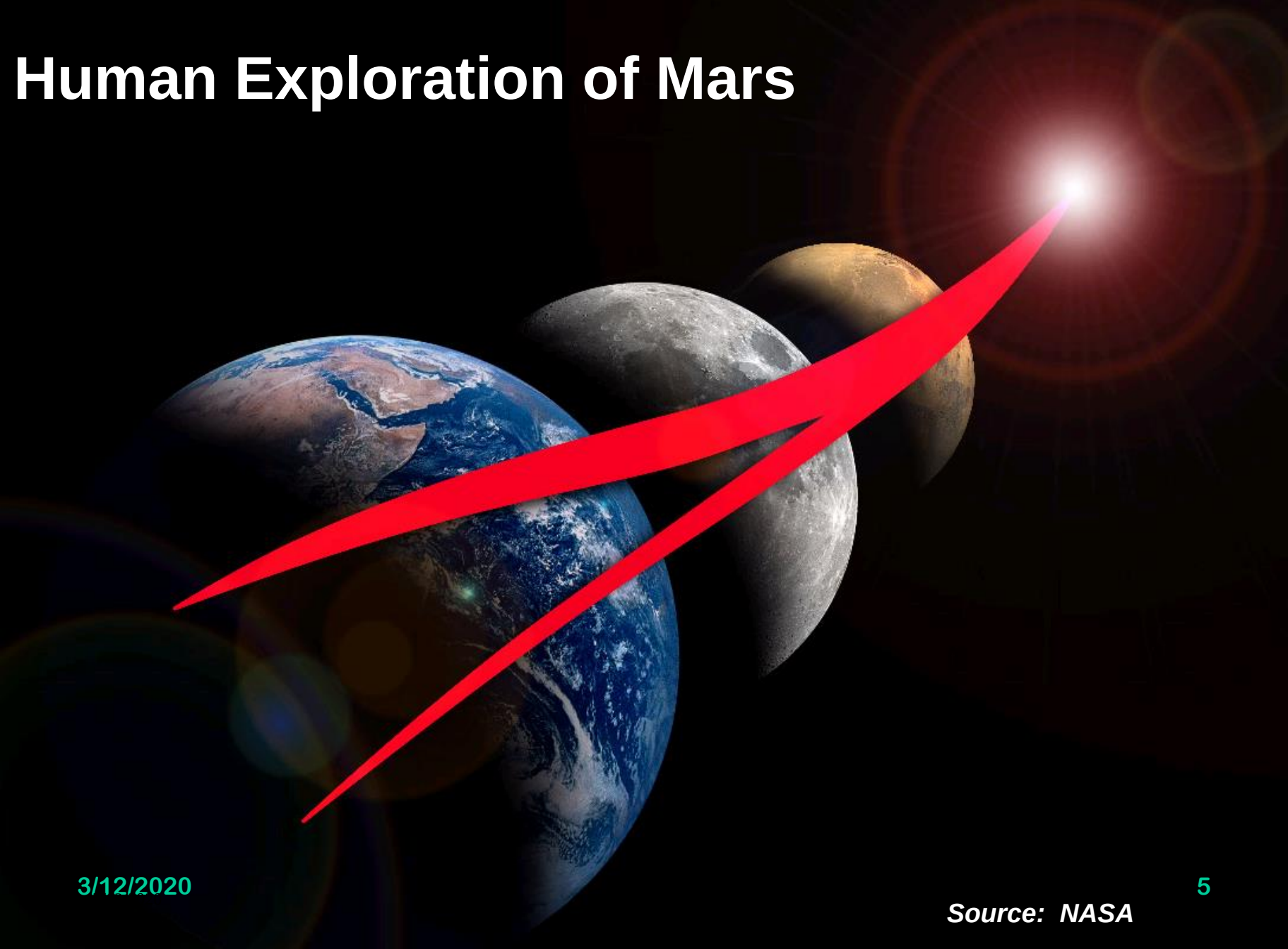
What Mars looks like with new instruments



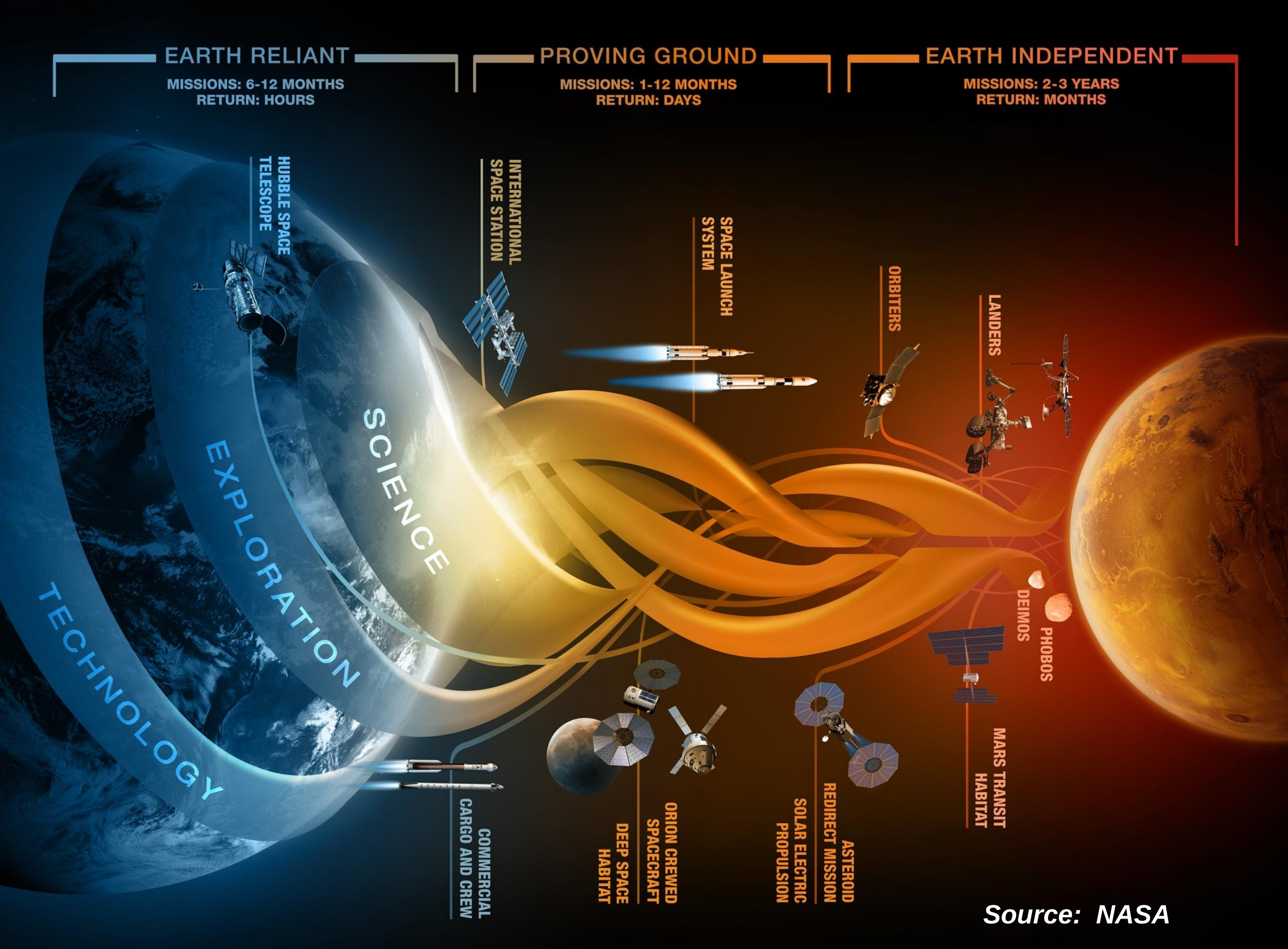


Source: JPL/NASA

Human Exploration of Mars

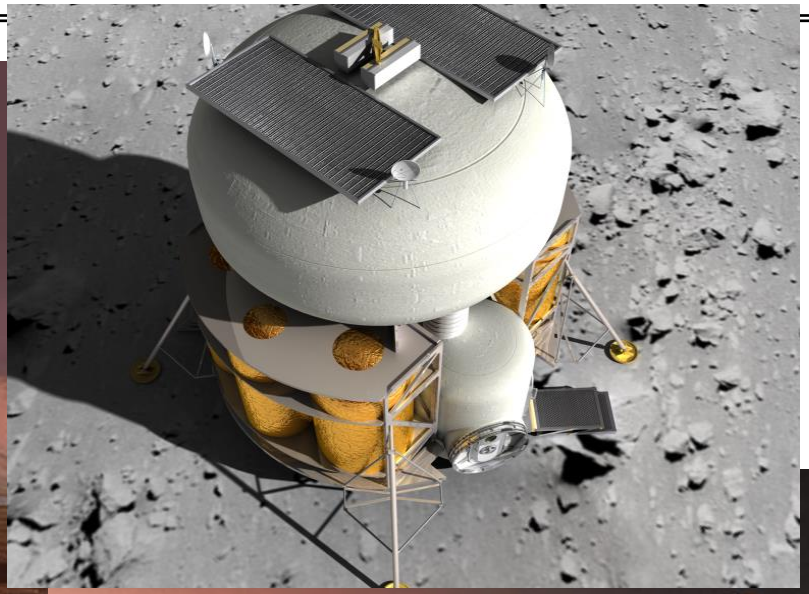


Source: NASA


EARTH RELIANT
MISSIONS: 6-12 MONTHS
RETURN: HOURS
PROVING GROUND
MISSIONS: 1-12 MONTHS
RETURN: DAYS
EARTH INDEPENDENT
MISSIONS: 2-3 YEARS
RETURN: MONTHS
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
COMMERCIAL CARGO AND CREW
DEEP SPACE HABITAT
ORION CREWED SPACECRAFT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION

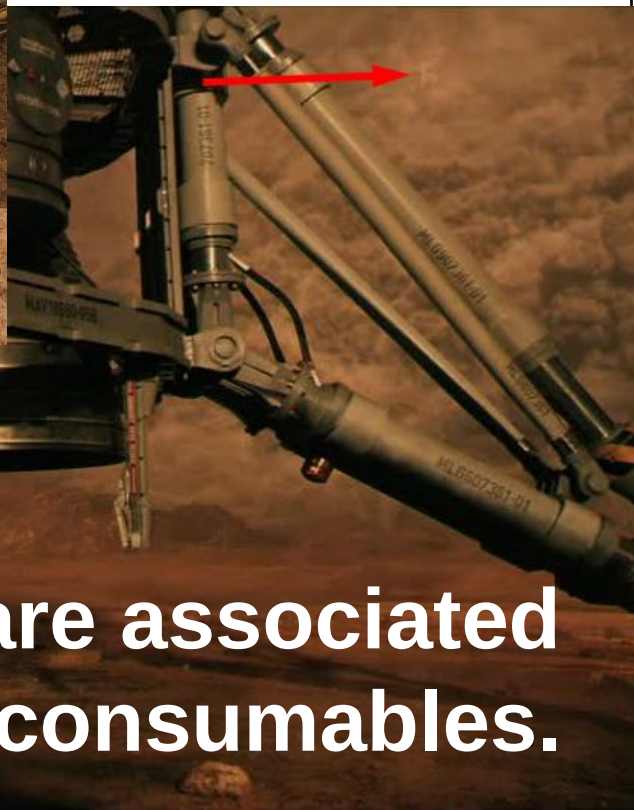
Source: NASA

Humans to Mars: Materiel



We need lots of equipment from Earth

Humans to Mars: Materiel



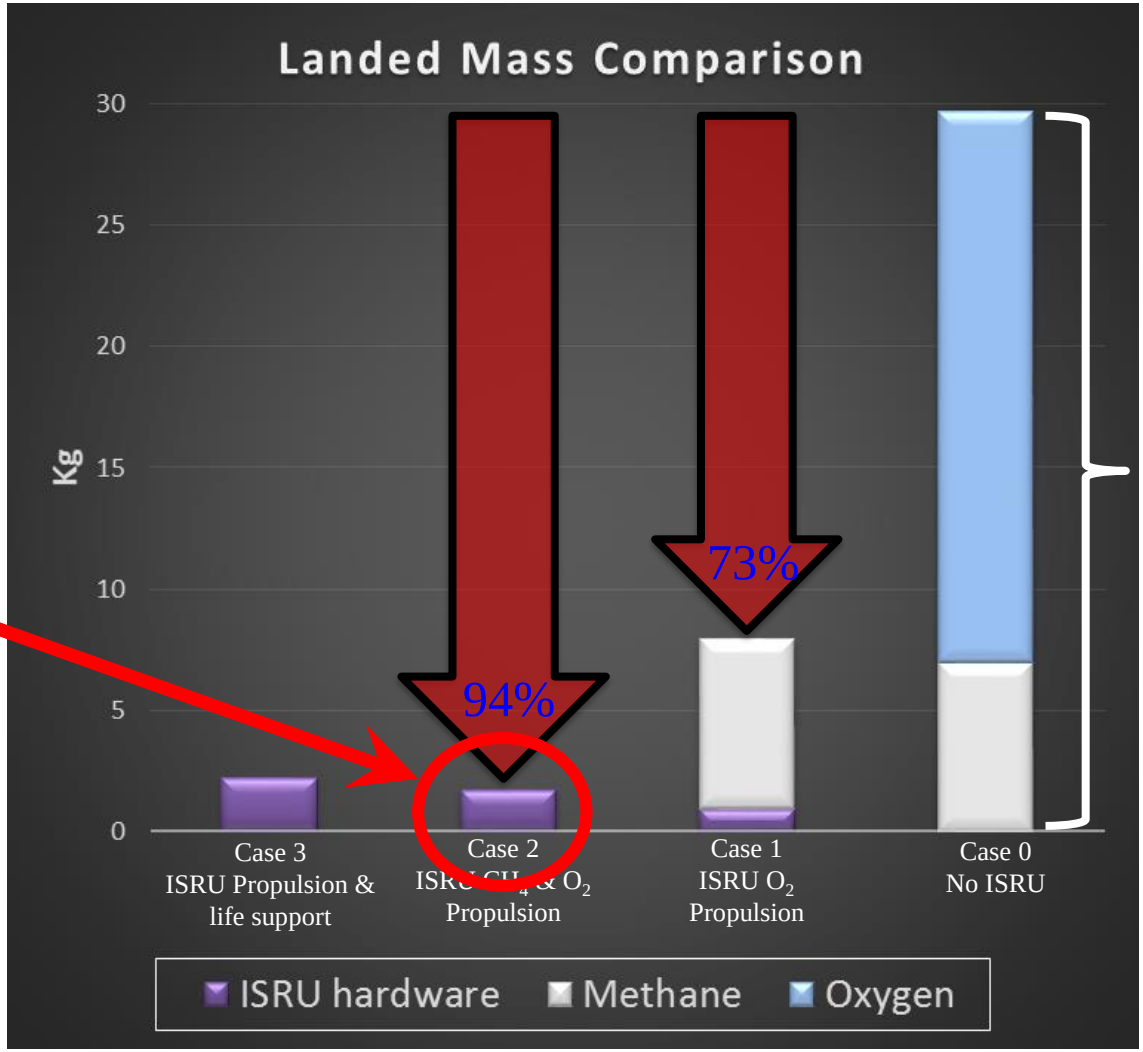
There are associated consumables.

The Problem/Opportunity

Two of the commodities needed by a human mission in large quantity exist at the martian surface.

A Critical Trade-off

Or we deliver this much equipment, and use local resources

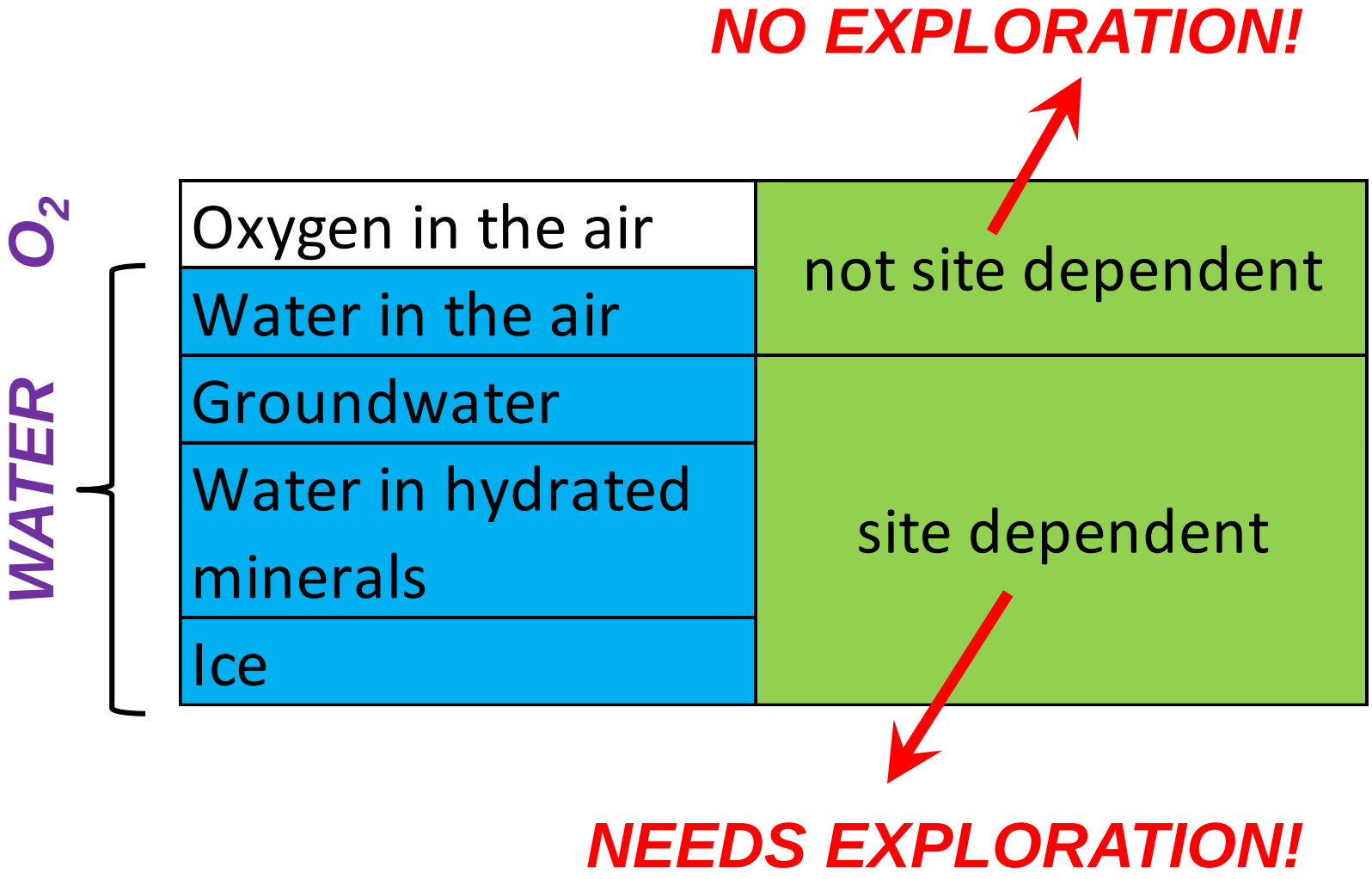


We either deliver these resources from Earth

Courtesy Julie Kleinhenz

What are the Mars resource options to supply these consumables?

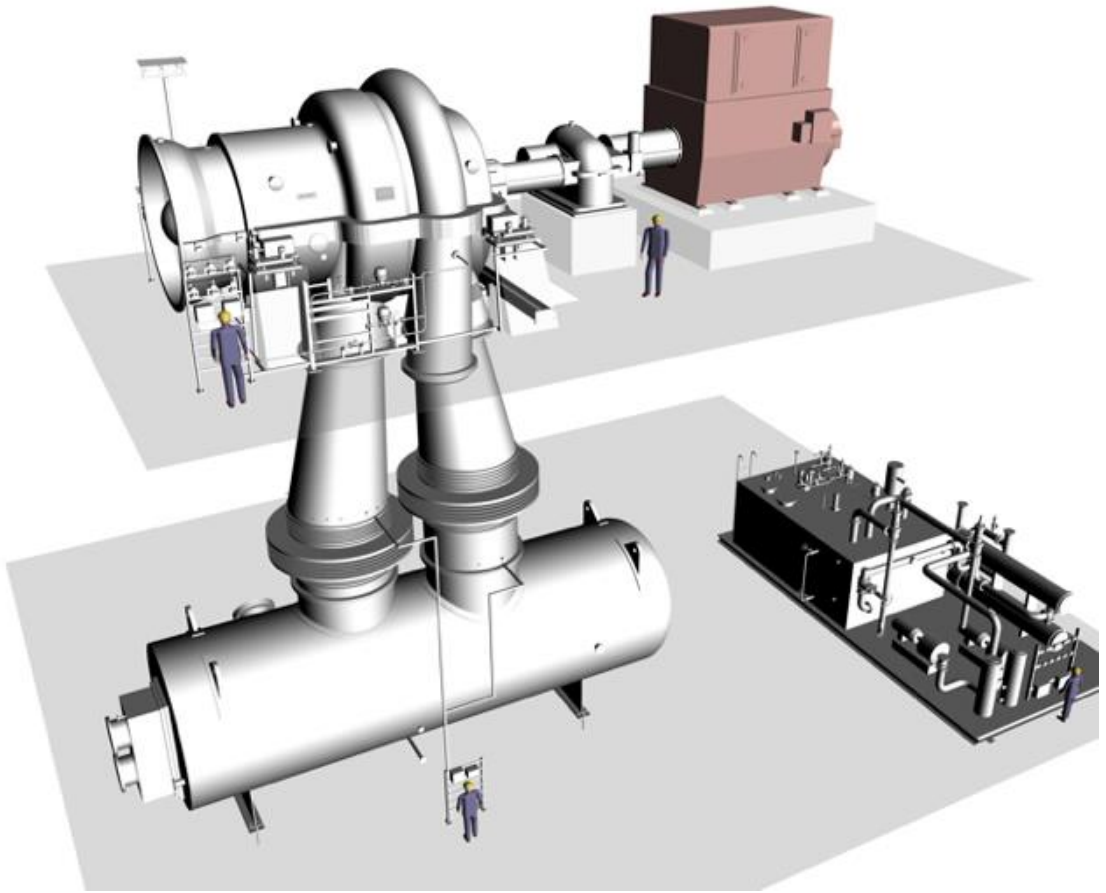
Main Martian Resources



WATER FROM THE AIR

Water in the Atmosphere

- To extract necessary amounts of water from air, we need ~**600,000 CFM**.
- Same order of magnitude as the largest air compressors on Earth:
- **65 megawatts, ~5x5x10m** in size.



Source: www

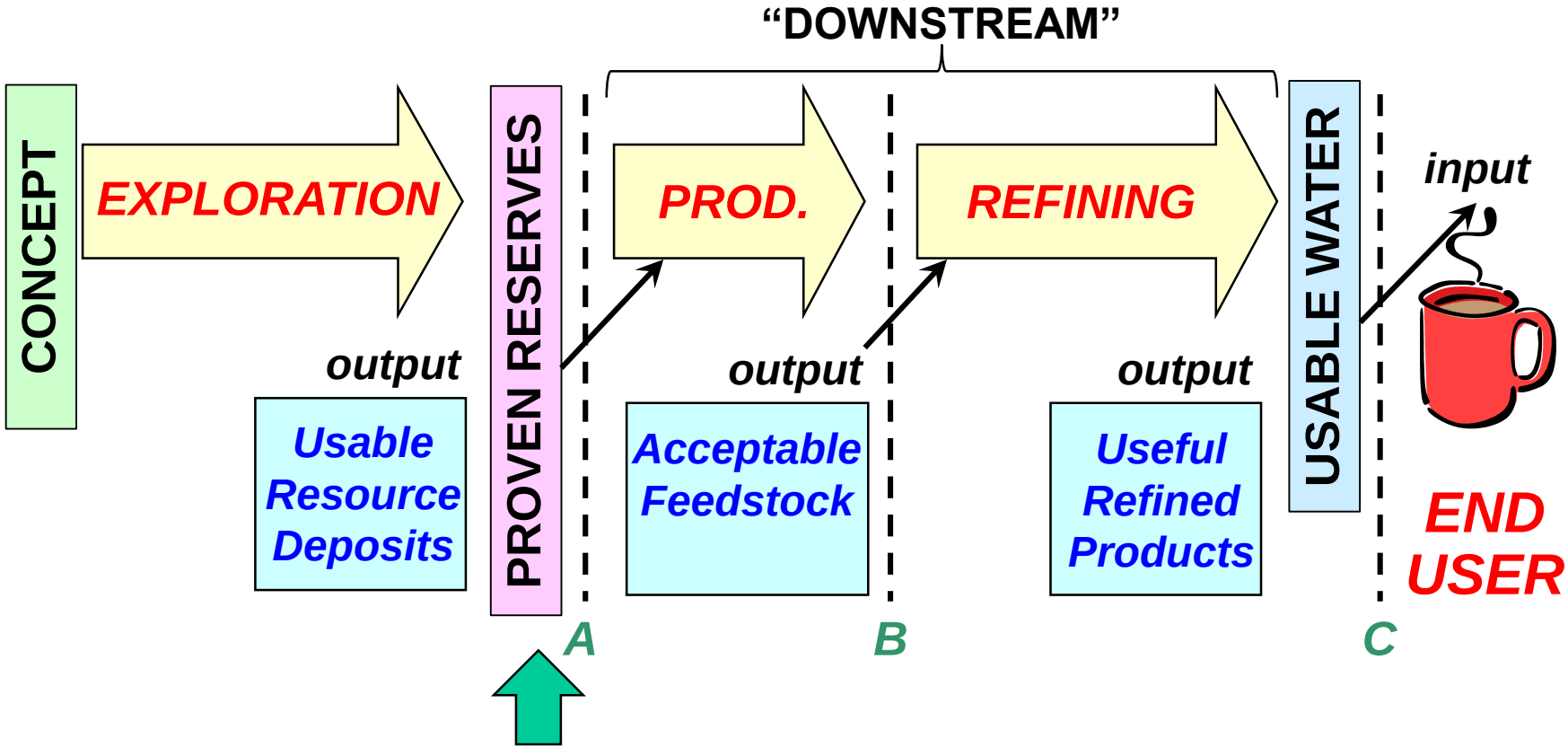
Story So Far

Oxygen in the air	not site dependent
~~Water in the air~~	
Groundwater	site dependent
Water in hydrated minerals	
Ice	

For water, exploration is required.

What have we learned in resource exploration here on Earth that can be applied to Mars?

The Exploration-Production Flow



"Reserves" are the essential interface between "exploration" and "production"

Confidence: The Concept of Reserves

Reserve Classification	Earth Application	Mars ISRU Application	Confidence
Proven	Use as collateral for a bank loan	Astronaut lives can depend on it	99%
	MAKE COMMITMENTS		
Probable	*SPECIFIC DEFINITIONS EXIST*	*UNDEFINED*	90%
Possible		*UNDEFINED*	50%
Potential	*THE EXPLORATION ARENA*		<50%

Some Lessons Learned on Earth

(and these will apply in spades on Mars)

Earth Experience Lesson #1

Cannot define a reserve without specifying how it could be produced.

- Critical link between science and engineering

Some Lessons Learned on Earth

(and these will apply in spades on Mars)

Earth Experience Lesson #2

Perfect knowledge is not possible (until after the fact)

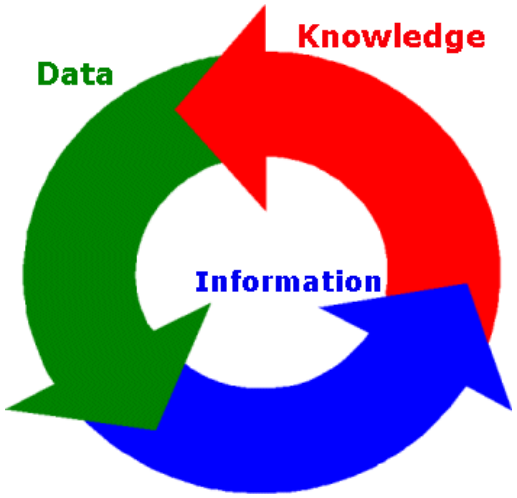
- How much uncertainty can be accepted?

Some Lessons Learned on Earth
(and these will apply in spades on Mars)

Earth Experience Lesson #3

All knowledge is not equally valuable

- Exploration is cost-constrained: You cannot afford to buy all of the information you want
- The decisions on which information to acquire can determine success/failure.
- Information acquisition decisions happen very early



Some Lessons Learned on Earth

(and these will apply in spades on Mars)

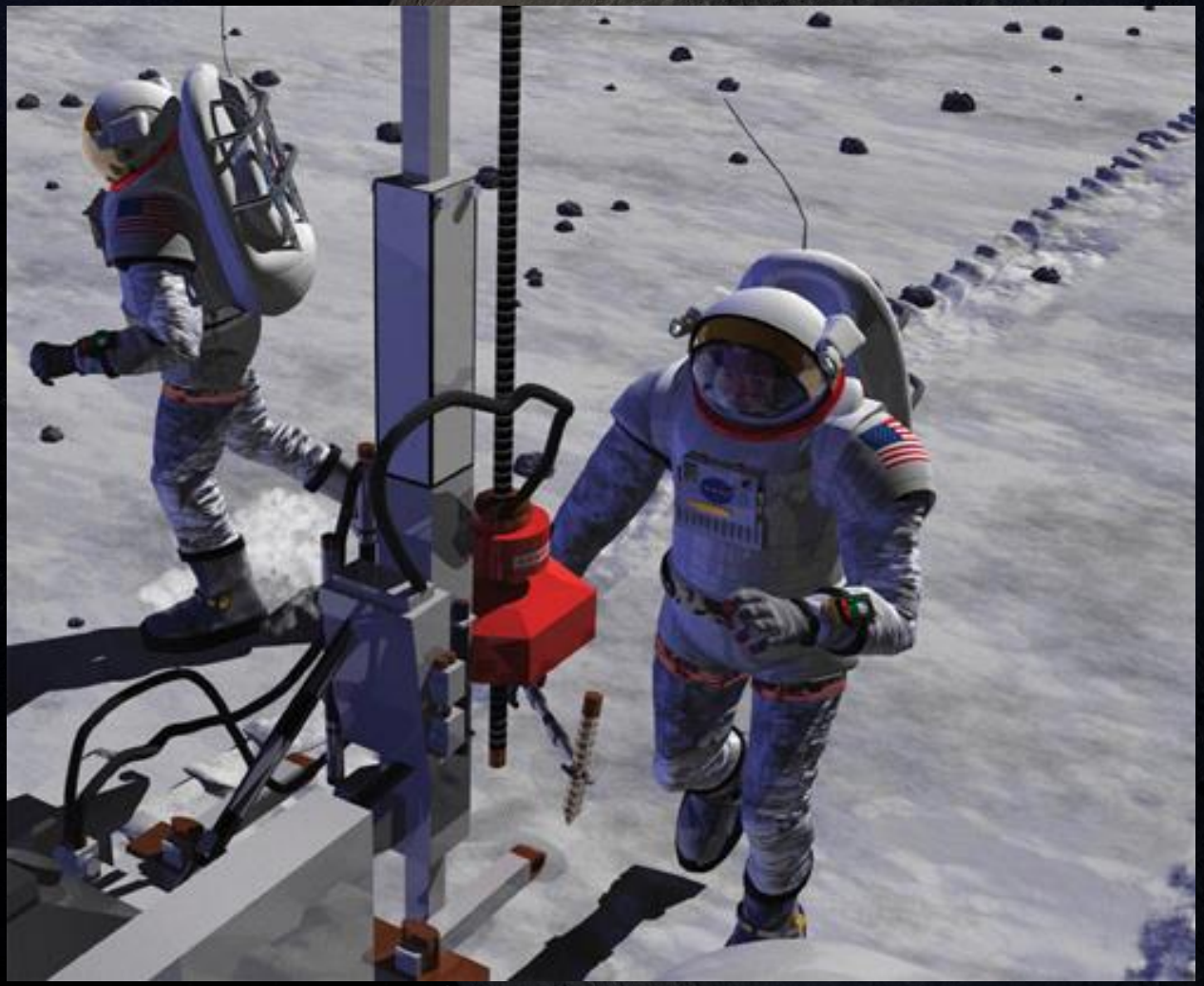
Earth Experience Lesson #4

If you assume reserves are there without sufficient exploration, update your resume first.

- Wishful thinking is not a substitute for scientific exploration.

GROUNDWATER

Groundwater

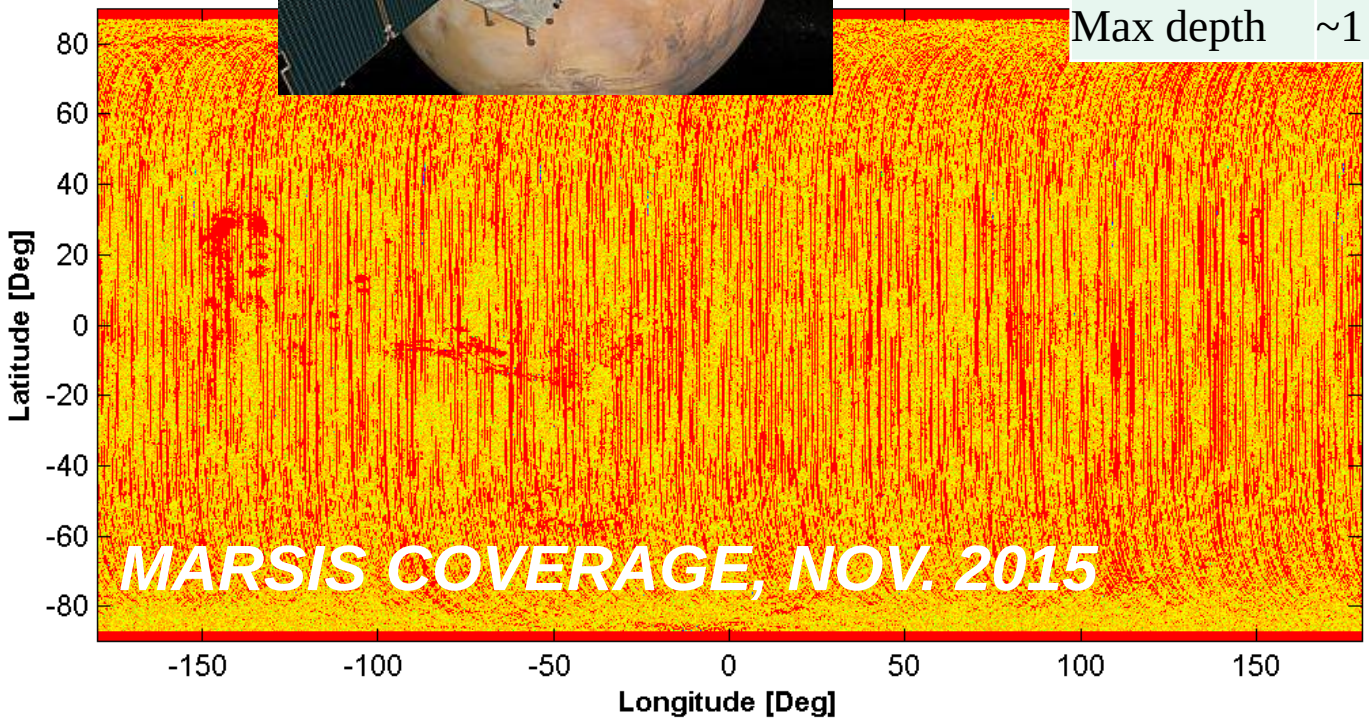


Next Step in Fulfilling Our Destiny As Explorers

Source: NASA

Geophysics

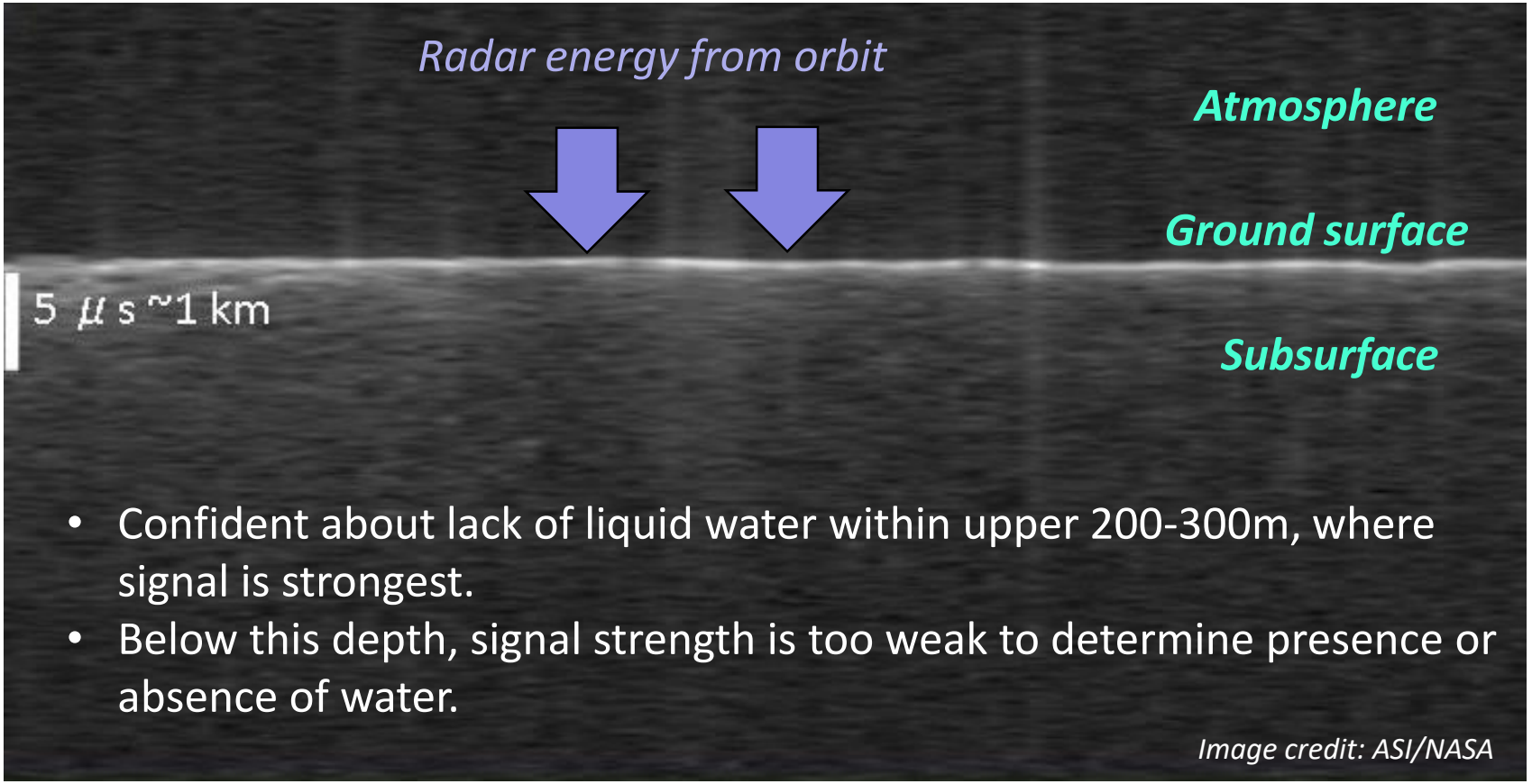
	MARSIS	SHARAD
Coverage	~69%	~31%
Spatial res.	~10 km	~0.5 km
Depth res.	~100 m	~10 m
Max depth	~1 km	~ 300 m



Map of Mars:
- *Yellow: Survey completed and no water detected (evidence of absence).*
- *Red: No data or SNR too low (absence of evidence)*

From Jeff Plaut; discussion with Rich Zurek, Serina Diniega

Geophysics



- Confident about lack of liquid water within upper 200-300m, where signal is strongest.
- Below this depth, signal strength is too weak to determine presence or absence of water.

The absence of radar reflections from below ground surface indicates no water table

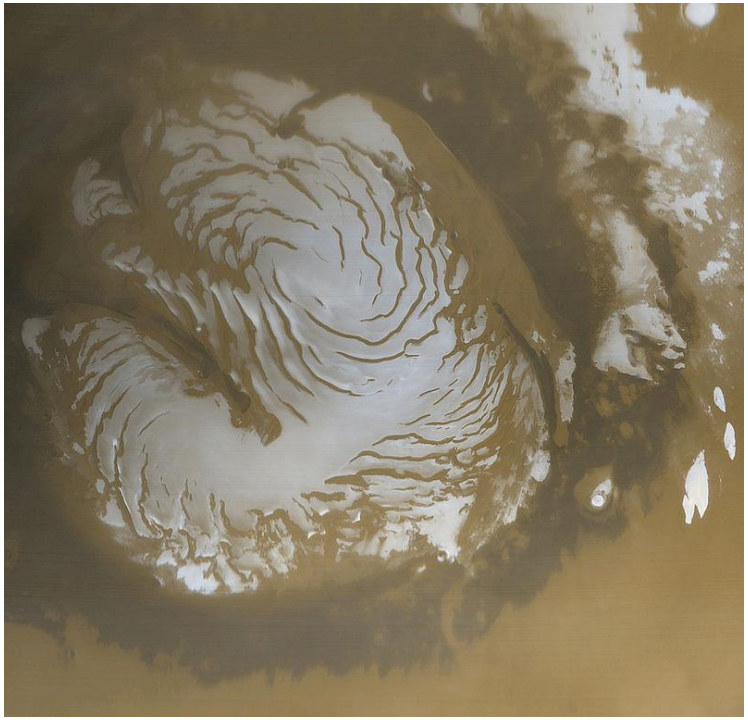
From Jeff Plaut; Rummel et al. 2014

Story So Far

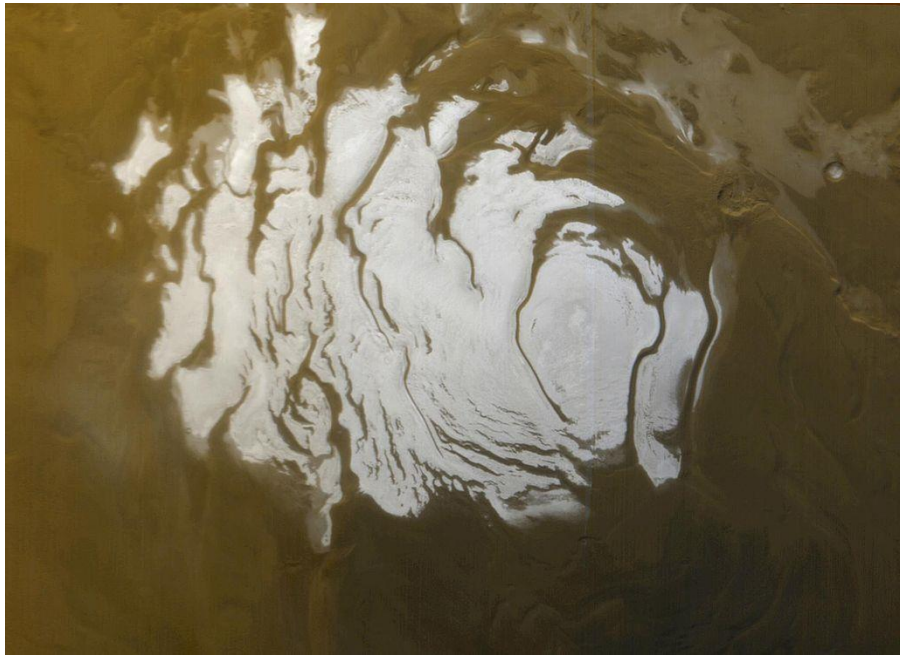
Oxygen in the air	not site dependent
~~Water in the air~~	
~~Groundwater~~	site dependent
Water in hydrated minerals	
Ice	

ICE

Polar Ice Caps



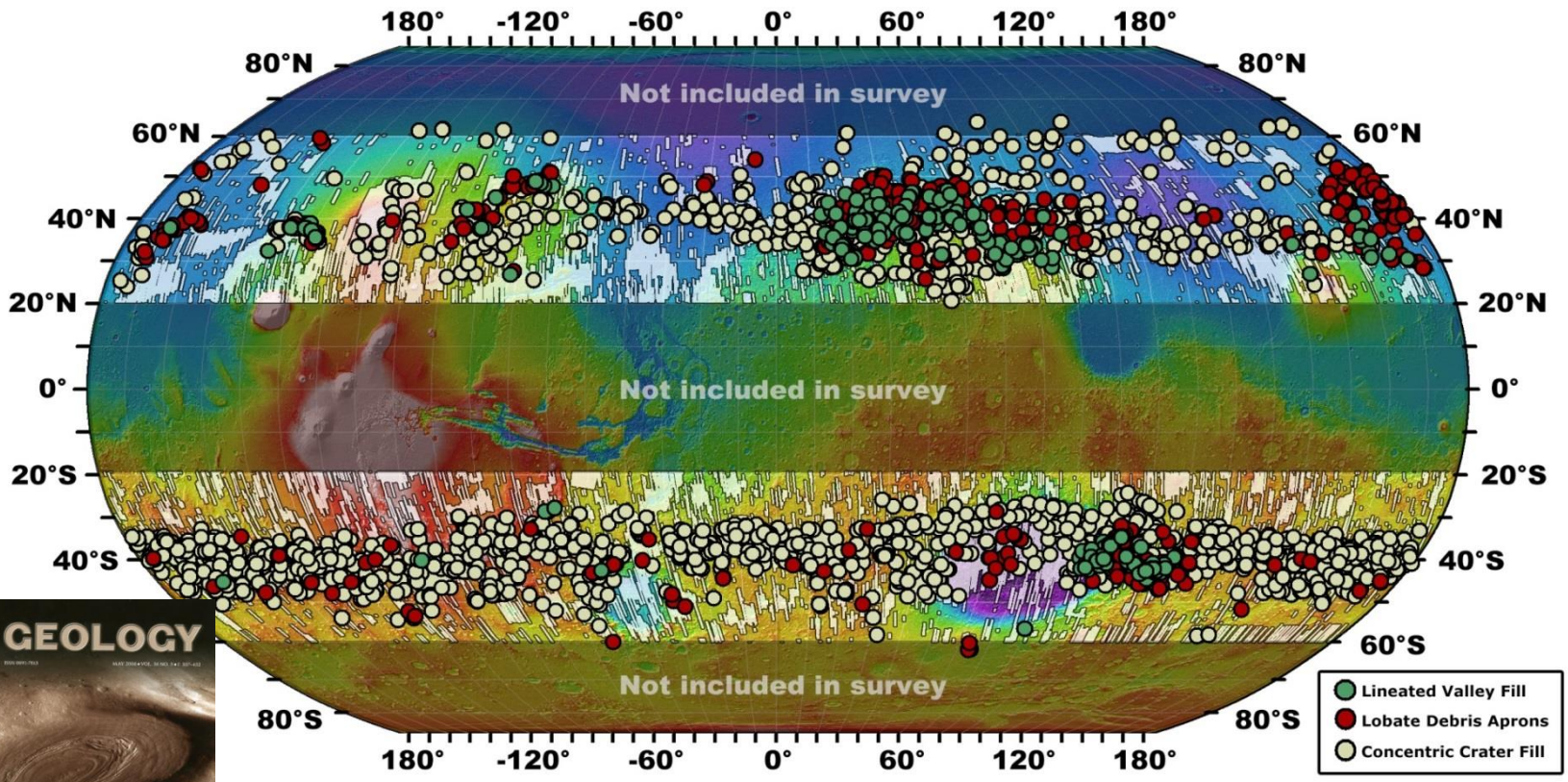
North polar cap in 1999



South polar cap in 2000

However, polar latitudes create severe engineering problems for human missions

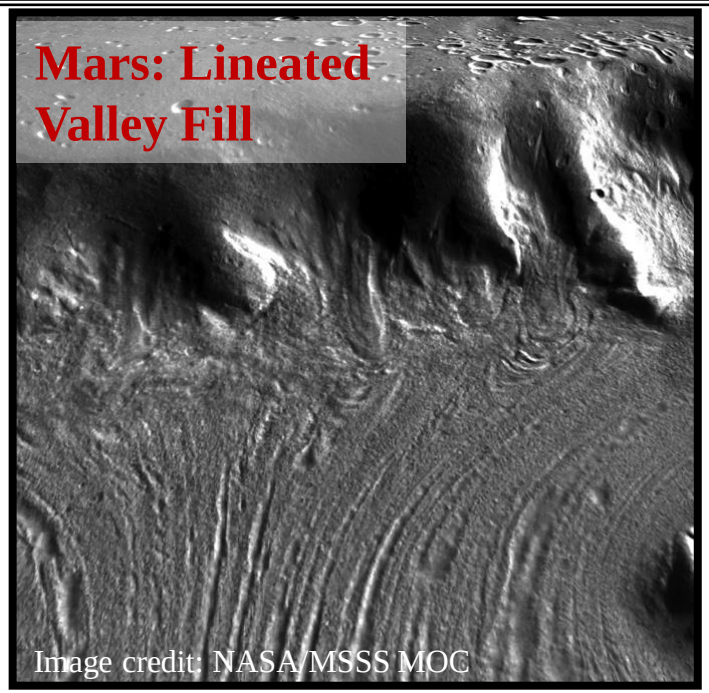
Mars Glacial Features

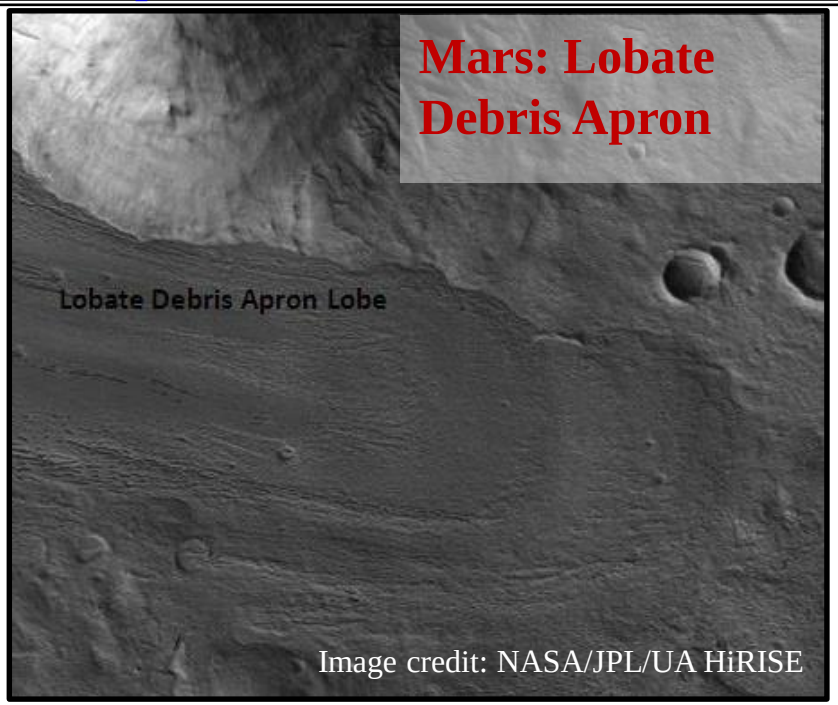


Mars has had ice ages that have left mid-latitude glacial deposits.

From Dickson et al., 2012; discussion with Jim Head acknowledged

Glacial Deposits on Mars: Examples



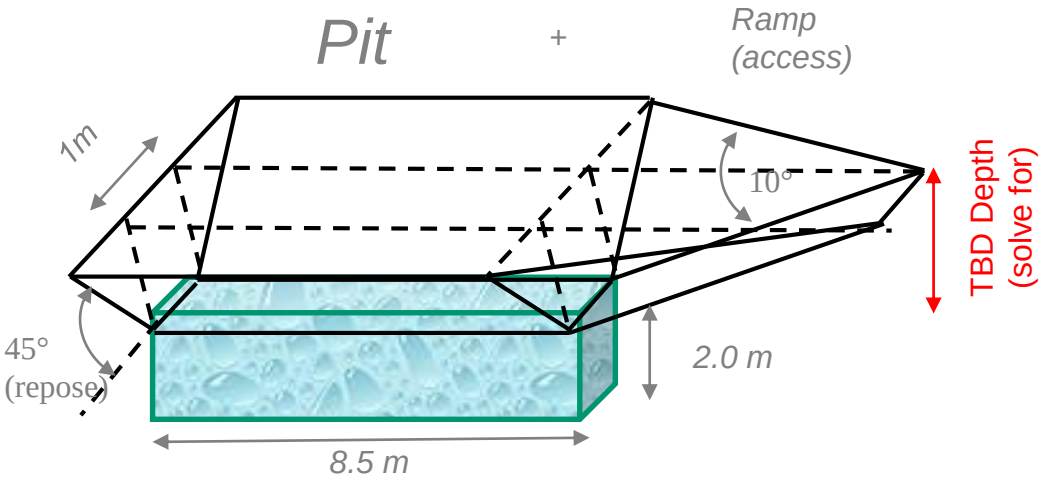


- Glacial ice is 100s of meters thick—potential quantities are huge.
- However, covered with sublimation till (the residue left as a result of ice sublimation) and rubble from outcrops.

Producing Water From Ice

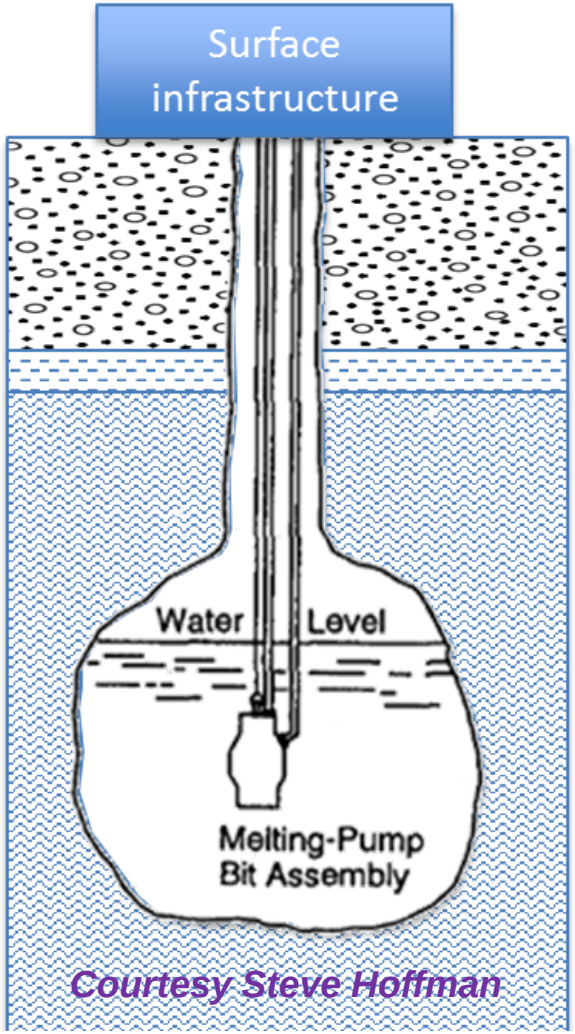
We have identified two possible production methods.

SMALL OPEN PIT



Courtesy Paul van Susante, MWIP (2016)

DRILL HOLE/ WELL

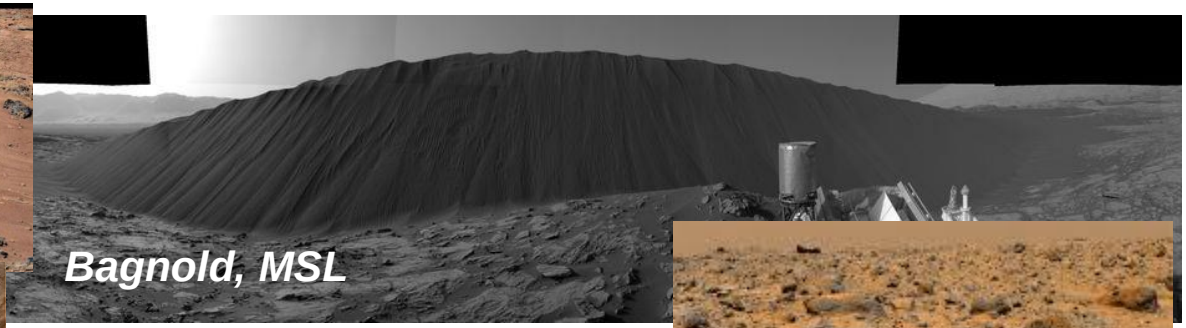


Courtesy Steve Hoffman

WATER IN GRANULAR MATERIALS

The Martian Regolith (Soil)

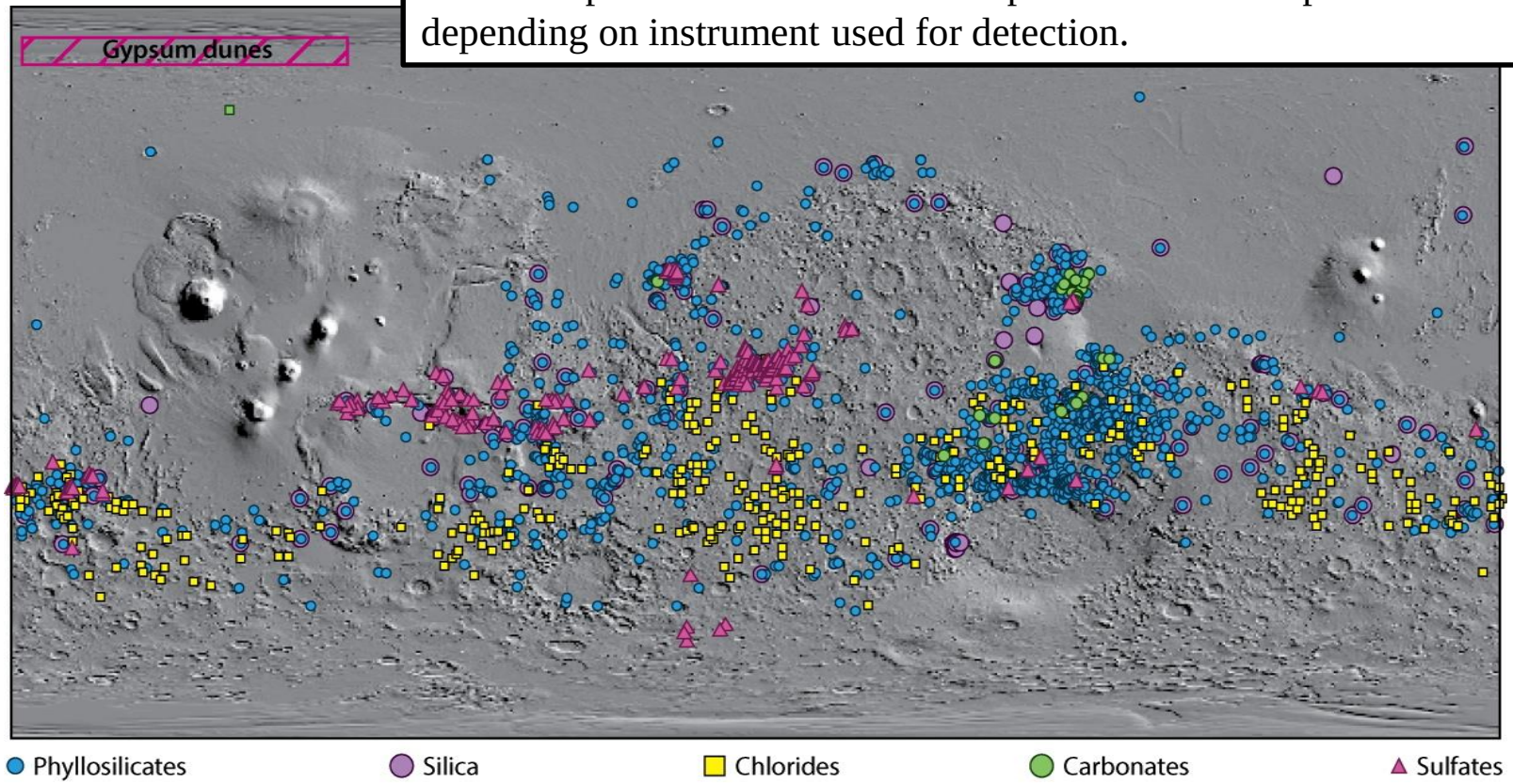
Contains > 1.5% water, but in hydrated minerals, not as “soil moisture content”.



Source: JPL/NASA

Map of Mars Mineral Detections

Note: footprint size is from 3x6km spots to 18-2000m/pixel depending on instrument used for detection.

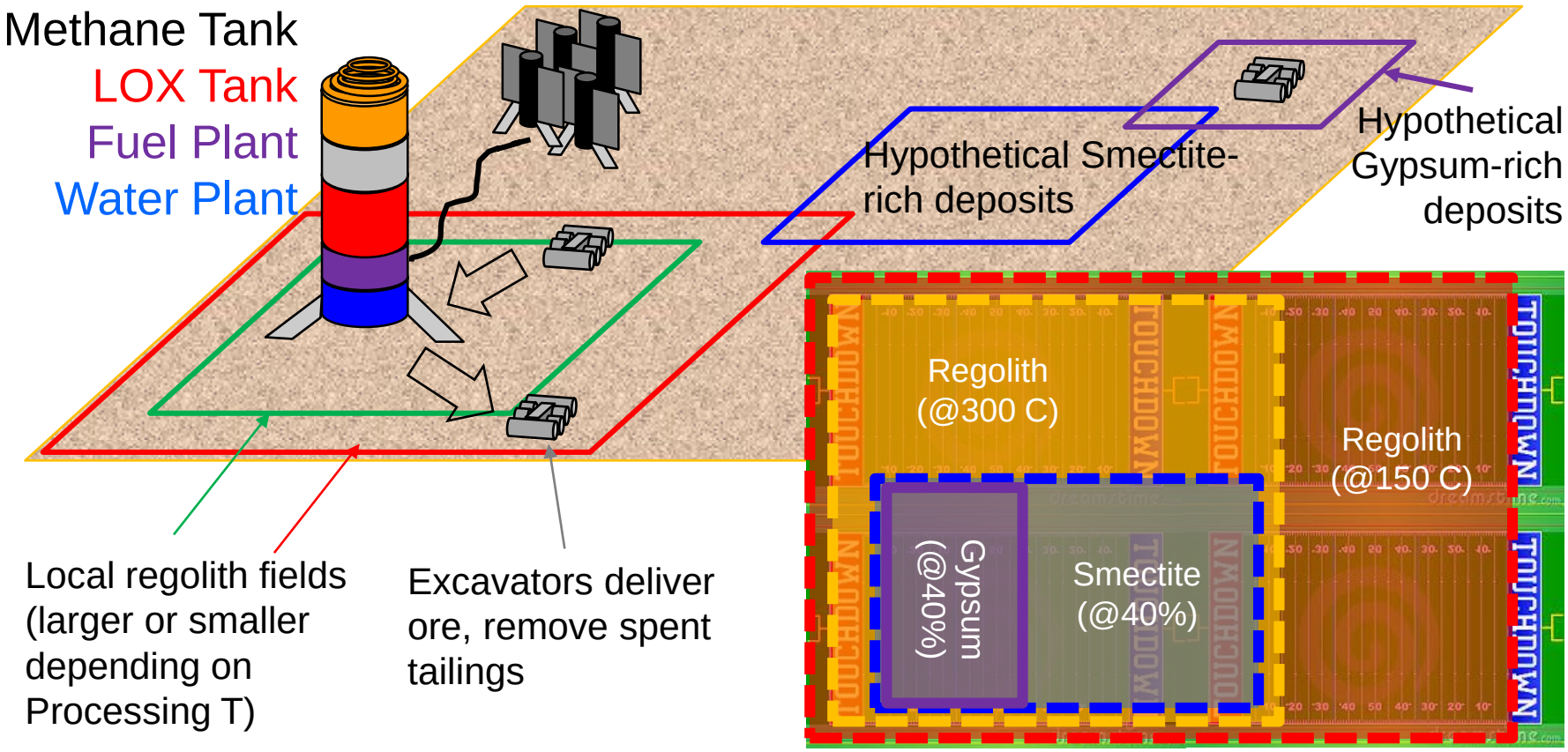


Master compilation of all Mars mineral detections.

From Ehlmann and Edwards (2014)

Granular Materials "Enterprise"

Possible layout of a minerals operation.

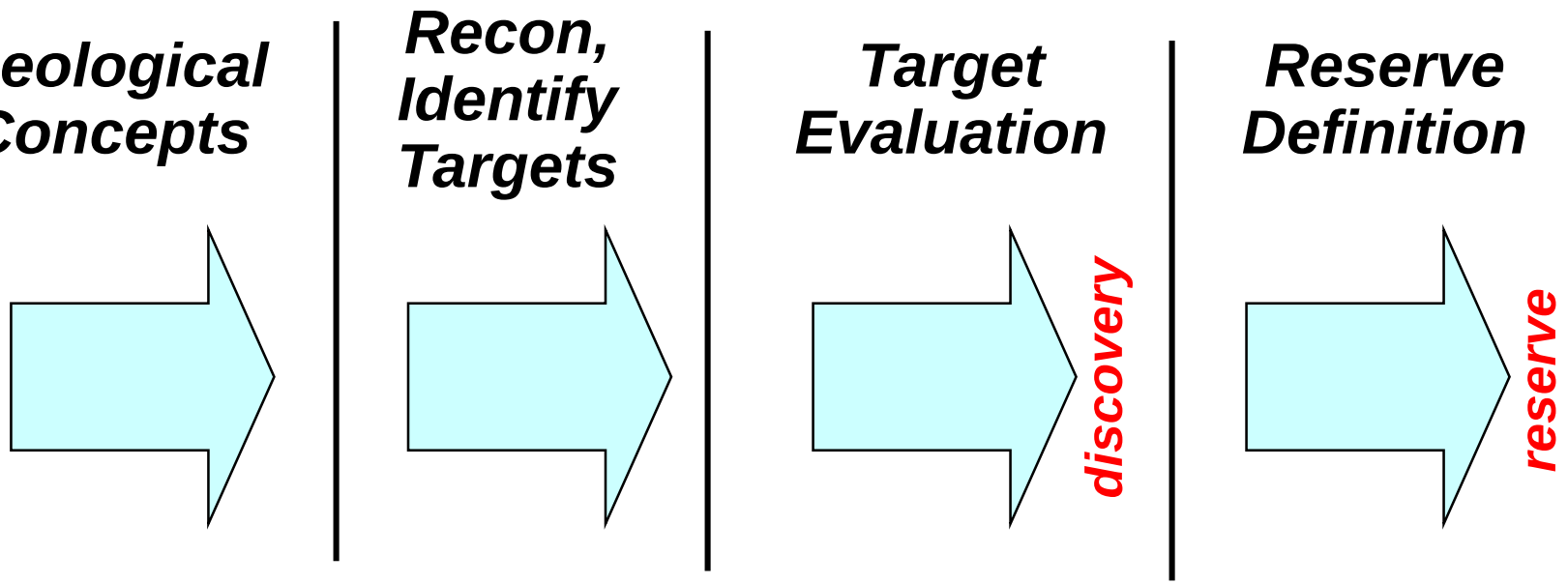


So what do we do?

PLAN a logical and systematic exploration program

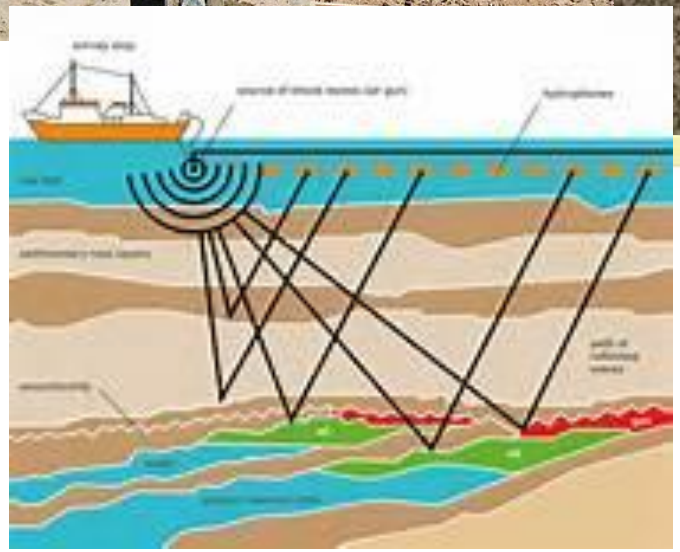
- This is not a one-mission problem
- Need to allow for enough time.

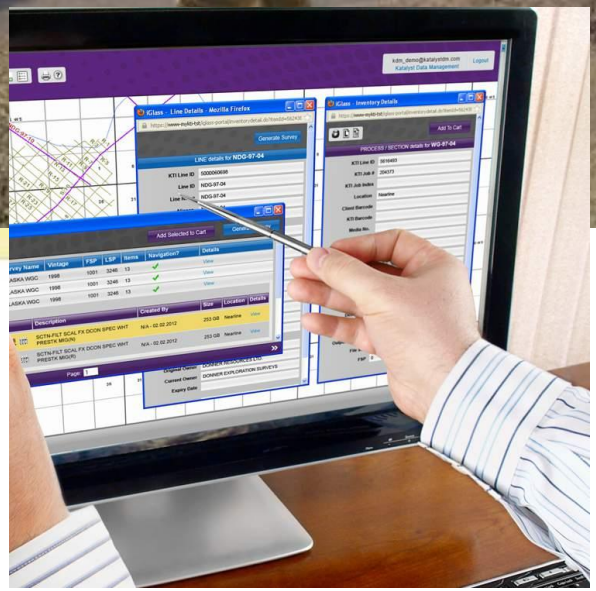
Classic Exploration Flow



Does Mars exploration have enough discipline to go through this resource exploration process?

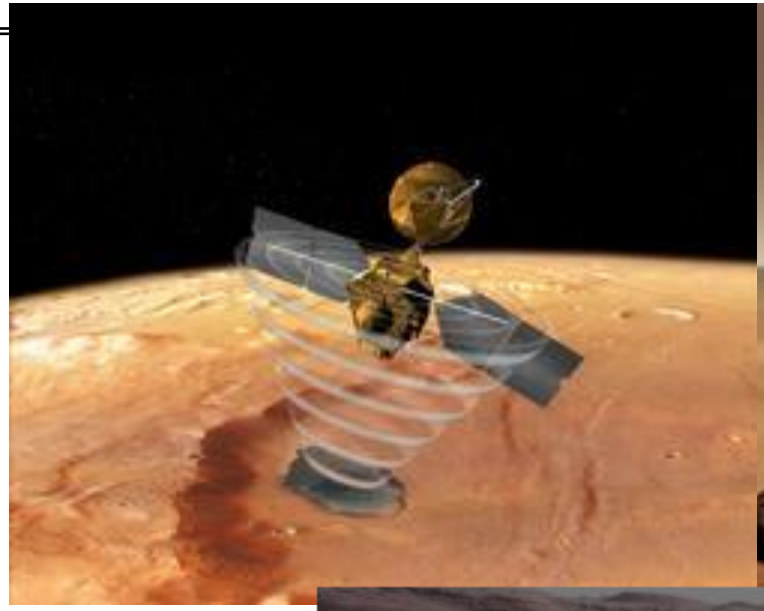
Exploration Process on Earth

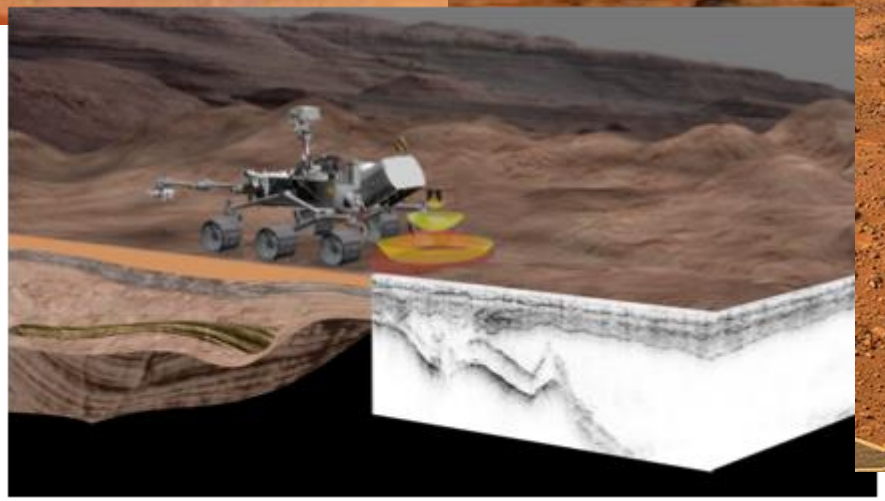


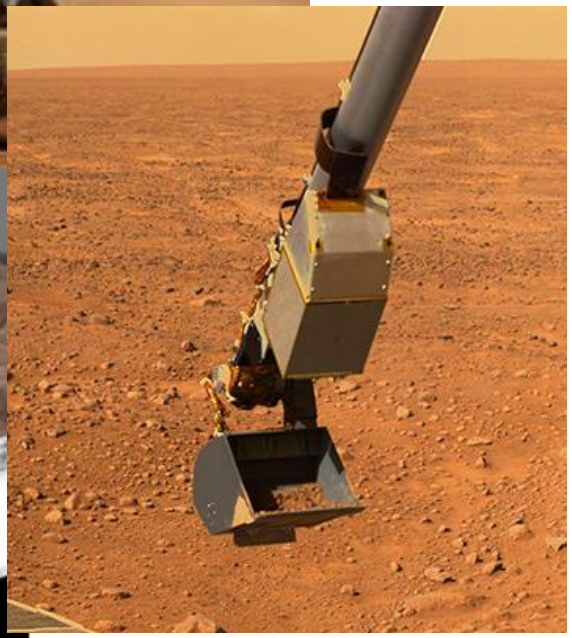


Source: www

Exploration Process on Mars







Source: JPL/NASA

In Conclusion

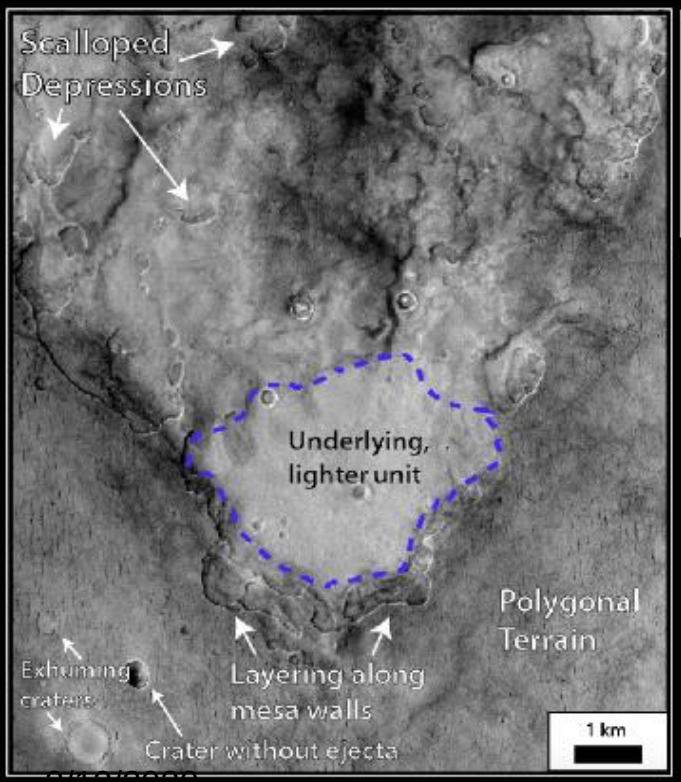
Source: JPL/NASA/MSS

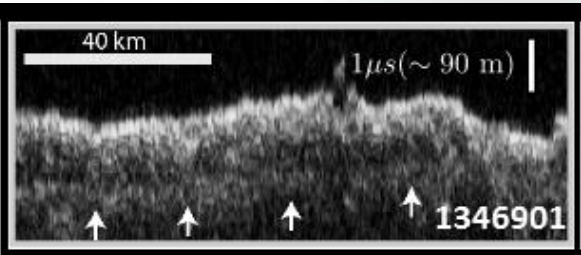
BACKUP

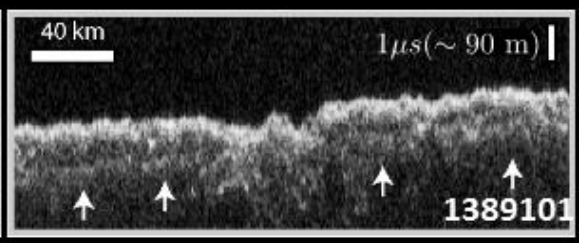
3/12/2020

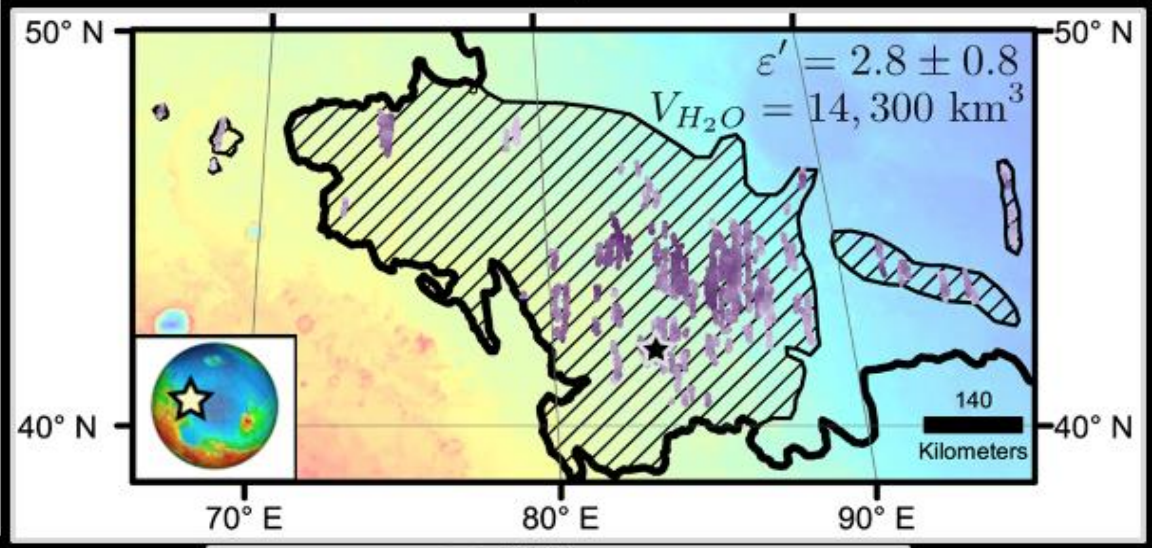
Detection and Characterization of a Very Large Subsurface Water Ice in Utopia Planitia, Mars

Using SHARAD radar data from the MRO spacecraft, a team led by Cassie Stuurman at the University of Texas at Austin has found roughly 14,000 cubic kilometers (about 1.2 times the volume of Lake Superior) of subsurface water ice in Utopia Planitia. This discovery confirms the idea of a water-ice cause for geologic features observed in the area, and it contributes to Mars' global inventory of water ice and to non-polar areas with resources potentially accessible during a human mission. **(Stuurman et al., Geophysical Research Letters, Sept. 28, 2016)**









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